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ON THE VARIATION OF THE STATOBLASTS OF PECTINATELLA MAGNIFICA FROM LAKE MICHIGAN, AT CHICAGO.

C. B. DAVENPORT.

THIS study is concerned with the hooks on the statoblasts of one of our common fresh-water Bryozoa — *Pectinatella magnifica* Leidy — taken in August, 1898, from the Jackson Park lagoon, Chicago, connected with Lake Michigan.

Pectinatella is a genus comprising two known species: Magnifica, found in the United States west of the Rocky Mountains, and elsewhere reported only from Hamburg, whither it has doubtless been imported; and Gelatinosa Oka, from Japan.[1] The most striking peculiarity of the genus is the close association of many colonies, which, by secreting together a gelatinous base, come to lie on the surface of a great globular gelatinous mass. One is inclined to think at first that the whole mass must have been produced by the activity of a single colony; but it is certain that it is due to the activity of a number of independent but associated colonies. The separate colonies are, however, probably all derived from a single statoblast, the descendant colony of which has repeatedly divided to produce the colony complex. Consequently, all the associated colonies are closely related; this has an important bearing on our results.

The statoblasts are formed inside of the colonies and frequently in large numbers. In twenty-seven colonies, in which all fully formed statoblasts were counted, the maximum number obtained was forty-six, the minimum was four; and the mode was at twenty to twenty-four. As all colonies contained developing, still immature statoblasts, these numbers would have been greater later in the season.

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[1] A possible third species of this genus has been named by Hyatt (**'66–'68**) *Pectinatella Carteri*, from a single statoblast described by Carter (**'59**), remarkable for its hooks, which grow only at the ends of the statoblast and which are furnished with many lateral claws.

The statoblast consists of a central, nearly circular, disk surrounded by a narrow, ring-shaped float. Placed radially at the margin of the statoblast are a varying number of hooks; the variability of this number was the starting point of the present investigation.

The statoblasts counted were found partly floating free in the preserving fluid and were partly picked out of the colonies, those from one colony being carefully kept together; 827 statoblasts were counted altogether, of which 635 came from known colonies.

Results. — The results of countings made on all statoblasts and on statoblasts from known colonies only is as follows:

Classes.	All Statoblasts.	Statoblasts from Colonies only.	Classes.	All Statoblasts.	Statoblasts from Colonies only.
11	11	7	17	23	18
12	106	79	18	2	1
13	265	201	19	2	2
14	238	186	20	0	0
15	122	93	21	1	1
16	57	47			

The quantitative study of these seriations gives the following constants:

	All Statoblasts.	Statoblasts from Colonies only.
n	827	635
M	13	13
A	13.782 ± .031	13.814 ± .036
ϵ	1.318 ± .022	1.326 ± .026
c	9.57 ± .16	9.60 ± .19
	F = − 1.758 Type IV Asymmetry = + 0.0766	

Conclusions. — Since the results based on "all statoblasts" and on "statoblasts from colonies" differ by less than their

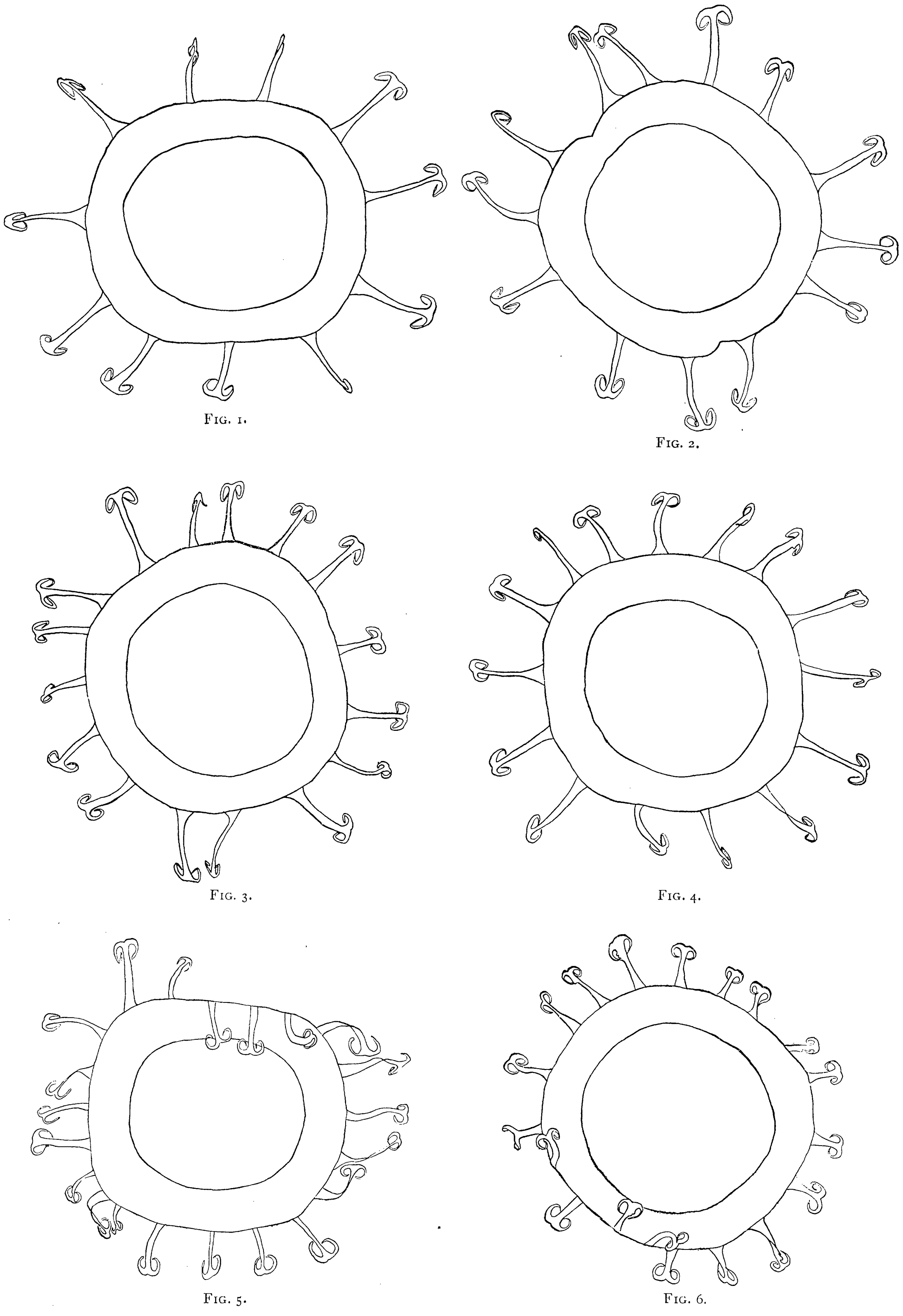

FIG. 1.

FIG. 2.

FIG. 3.

FIG. 4.

FIG. 5.

FIG. 6.

FIGS. 1–6. — Outline camera drawings of statoblasts of Pectinatella showing variation in the number of hooks. 1. 11 hooks. 2. 13 hooks. 3. 15 hooks. 4. 16 hooks. 5. 18 hooks. 6. 21 hooks. Compare the length of the hooks in Figs. 1 and 5. × 45.

probable errors, we need discuss only the larger collection of 827 statoblasts.

The mode is 13, the range from 11 to 21; or, omitting the single statoblast with 21 hooks, the range is 11–19 (Figs. 1–6). Statoblasts from Fresh Pond, Cambridge, Mass., are stated by Hyatt to have had, in 1866, 12–17 hooks; and those of Pennissewassee Pond, Maine, 20–22 hooks. The statoblasts of *Pectinatella magnifica* which Kraepelin found at Hamburg varied like those at Fresh Pond, 12–17.

The mode lies over toward the lower limit of the range; consequently the mean lies above the mode and the skewness is rather large, + 0.077.[1] The index of variation (ϵ) is rather large as compared with that of other integral variates. The coefficient of variation (c) is also large as compared with that derived from some graduated variates, as the following series shows:

ORGAN.	INDEX OF VARIATION.	MEAN.	COEFFICIENT OF VARIATION.
Rays of dorsal fin, Acernia	[2]0.6040	14.16	4.266
Müllerian glands of swine	1.6808	3.50	48.009
Rostral teeth *Palæmonetes varians*	0.8627	4.31	19.999
Height of U. S. recruits	2.5848 in.	67.30 in.	8.689
Height of St. Louis schoolgirls, aged 8	5.5524 cm.	118.27 cm.	4.698
Length-breadth index, Bavarian skulls	3.468 mm.	83.07 mm.	8.621
Length right human ♂ femur	23.72 mm.	452.28 mm.	5.425
Length right radius human ♀ radius	10.95 mm.	214.86 mm.	5.096
Angle of neck of femur with shaft	5.578°	124.26°	4.469
Maximum length of clavicle ♀	9.208 mm.	136.85 mm.	6.724
Sacral index ♂	9.353%	115.000%	8.137
Scapular index	3.815%	65.900%	8.575
Infra spinous index of scapula	8.572%	89.454%	9.893

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[1] For comparison I introduce some skewness determinations of other qualities:

Pearson, '**95**, Weldon's crab measurements, "No. 4"	+ .077
" " Baxter's height of 25,875 recruits, U. S.	– .038
" " Porter's height of 2192 St. Louis schoolgirls	– .049
" " 900 Bavarian skulls: length-breadth index	+ .032
" " dorsal teeth of *Palæmonetes varians*	+ .130
Pearson & Filon, '**98**, Müllerian glands of swine	+ .311
Rays of Pecten, lower valve	+ 0.023
" " " upper "	+ 0.0000000058

[2] The first three data are derived from counting. They are integral variates. In them we see that the index of variation is more constant than the coëfficient

The curve is of Type IV, or has unlimited range, like most biological curves. The skewness of the distribution indicates possibly a selective weeding out of statoblasts with a small number of hooks. Such a result is not unlikely, for (within certain limits) we might expect statoblasts with a larger number of hooks to have a better chance of keeping their hold and forming new colonies than those with fewer hooks. On the other hand, the skewness may mean a tendency of the species to give rise to races with a larger modal number of hooks than 13. Such a race has been formed in Maine (Hyatt) ; and in *P. gelatinosa* the number of hooks is said to be "great" (Oka).

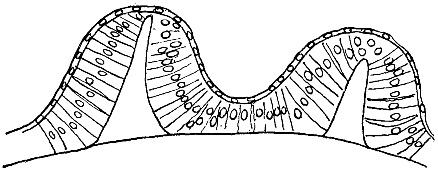

Fig. 7.

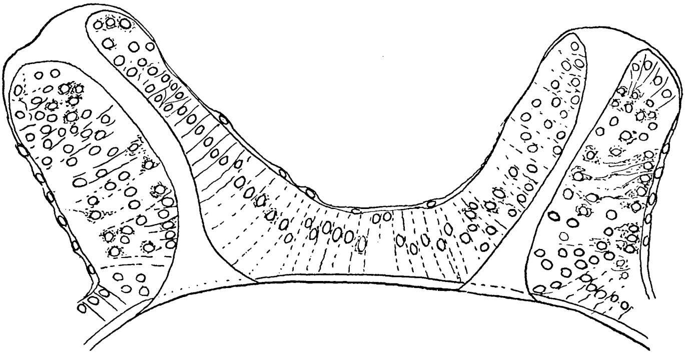

Fig. 8.

Fig. 7. — Early stage in formation of hooks. Section taken in the plane of the float and at its outer margin. ×

Fig. 8. — Later stage in formation of hooks. Section taken as in Fig. 7. × ca. 400.

We have next to consider the question whether there is an hereditary tendency to produce a certain constant number of

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of variation, and it is doubtless to be preferred to the coefficient. In the remaining cases, which are graduated variates, the coefficients are the more constant, varying from 4 to 9, whereas the indices vary from 2 to 23. Doubtless here the coefficient is to be preferred; moreover it is an abstract number, so that the results are comparable, whether millimeters, inches, degrees, or percentages are employed as units of measurement.

hooks in the same colony; or, in other words, whether the variability in the number of hooks found on statoblasts of the same colony will be less than the variability of the statoblasts from all the colonies taken together. To answer this question, I selected the eleven colonies showing the greatest number of statoblasts, and determined for each colony the ϵ and the c. Then I averaged the ϵ's and the c's for the eleven colonies, and compared these averages with the ϵ and the c of the 635 statoblasts coming from known colonies considered together. If the average ϵ or c of statoblasts from the same colony is no less than the ϵ or c of the population at large, there is no heredity. If, on the other hand, the ϵ's and c's of the colonies average zero, so that the differences between the variability inside the colony and in the whole population is the greatest possible, then there is the strongest possible heredity. In general, the percentage which the difference between the averaged ϵ or c is of the ϵ or c of the whole population, subtracted from unity, will serve as an index of heredity. I find:

	ϵ	c
Average for 11 colonies,	1.197	8.772
All statoblasts from colonies,	1.326	9.597

Index of relative heredity based on ϵ, $1 - \frac{1.197}{1.326} = 1 - 0.9027 = .0973.$

" " " " " " c, $1 - \frac{8.772}{9.597} = 1 - .9140 = .0860.$

The hereditary tendencies inside the colony are thus seen not to be very strong when compared with the tendency to similarity between all the statoblasts of the complex of colonies. I interpret this to mean that there is a close relationship between all the colonies in the complex.

The question next arose, what is the ontogenetic explanation of this variation?

To get some light on this matter, I studied the method of development of the hooks. As already stated, the hooks arise at or near the outer margin of the ring-shaped float; there is a little variation in the line of origin. Even after the float has been formed, the statoblast is clad externally with cells. Those at the outer edge of the statoblast are narrow and elongated perpendicularly to the surface of the statoblast. Between the cells are large water spaces, which may indicate that the hook-forming layer is turgescent, at least at the time of forming hooks.

The first step in the formation of a hook is a fold (Fig. 7). As many folds arise at about the same time as there are hooks. Consequently the number of hooks is determined by the number of folds, and the question of the cause of variability is transferred to the folds. I had thought at first that each fold might be derived from one cell, but since the hook-forming layer spreads over the forming float and consists already of numerous columnar cells, it would be difficult, if not impossible, to demonstrate this if it were so. The forming papilla is made up of 100 to 200 cells at its beginning. In its center is a core, filled with a secretion, which hardens to form the shaft of the hook. The prongs are secreted as a superficial cuticula at the apex of the papilla (Fig. 8). From this it will be seen that my hypothesis was incorrect, and I find in the embryology no ground for referring the number of hooks to a predetermining number of hook-forming Anlagen.

It is possible that the number of papillæ may be correlated with a variation in the perimeter of the statoblast, so that the number of hooks per unit of perimeter is constant. To settle this question, I measured the perimeter[1] of 125 statoblasts. I found these measurements interesting in themselves. The modal perimeter of the statoblasts was about 3.3 mm. The average was 3.319 ; $\sigma = .06649$ mm. ; and $c = 2.00$, a remarkably low variability, almost one-fifth that of the number of hooks. By the use of the Galton-Pearson-Duncker[2] method of calculating correlation, I found the correlation between the number of hooks and the length of the periphery of the statoblast to be $r = -.0920 \pm .0055$, a very low correlation, but slightly negative. I give the correlation surface :

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[1] The perimeter was measured by finding the length of a camera outline by means of the map-measure described in my *Statistical Methods* (New York, John Wiley & Sons, 1899).

[2] The reviewer of my *Statistical Methods*, in *Nature*, Dec. 14, 1899, says : " On p. 33 we notice a lengthy method, quoted from Duncker, given for reducing the product sum ; this should be replaced by the ordinary straightforward process of reduction to the mean." Although I have been satisfied of the correctness of Duncker's formula, which is got from Pearson's by a process of simplification, I calculated r by Pearson's method. Using logarithms, this took about four hours ; whereas to calculate r by Duncker's method took in this case about twenty minutes. The results differed by .001. The length of Pearson's process is a great obstacle to its use.

X_2	X_1	11	12	13	14	15	16	17	18	19
255–59.9	1					1				
260–64.9	2				1					
265–69.9	3			3	2	1				
270–74.9	4		5	14	12	7	4			1
275–79.9	5		1	18	6	2	5	1	0	1
280–84.9	6	1	3	15	6	4	3			
285–89.9	7			3	0	0	1			

$$X_1 \begin{cases} A = 13.8264. \\ \epsilon = \ 1.3403. \end{cases} \qquad X_2 \begin{cases} A = 4.8182. \\ \sigma = 1.0499. \end{cases}$$

The negative correlation between length of periphery and number of hooks signifies that in the long run small statoblasts tend to have slightly more hooks than large statoblasts, a result which we should hardly have anticipated. The result makes it clear that the number of hooks which shall develop is not determined by the space at their command for development. In a statoblast with eleven hooks, these are twice as far apart as in a statoblast with twenty-one hooks. The ontogenetic cause of the variation in number of folds remains thus still undetermined.

Although the *number* of hooks is not directly correlated with the periphery of the statoblast, it is rather strongly correlated with the *length* of the hooks ; and the correlation is inverse. This is quite striking from superficial observation. To express the relation in a roughly quantitative way, I measured a representative lot of the hooks on each of ten statoblasts. In eight statoblasts having thirteen or fourteen hooks the average length of the hook was about .22 mm. ; in the two with sixteen hooks the average length was .19 mm. The figures of statoblasts accompanying this paper will show that at greater extremes the difference in the hooks is still greater.

As the hooks decrease in size with increase in number, we might expect to find the hooks very small in the statoblasts with many of them. Such apparently is the case, for Oka states that the numerous hooks of *P. gelatinosa* are "minute," projecting beyond the annulus only 0.02 to 0.03 mm.

In studying the hooks, I came across a number of interesting abnormalities that are, indeed, rather common. As already stated, there are typically two claws at the distal end of the hook. The abnormalities concern chiefly these claws. They may be grouped under four types (Fig. 9):

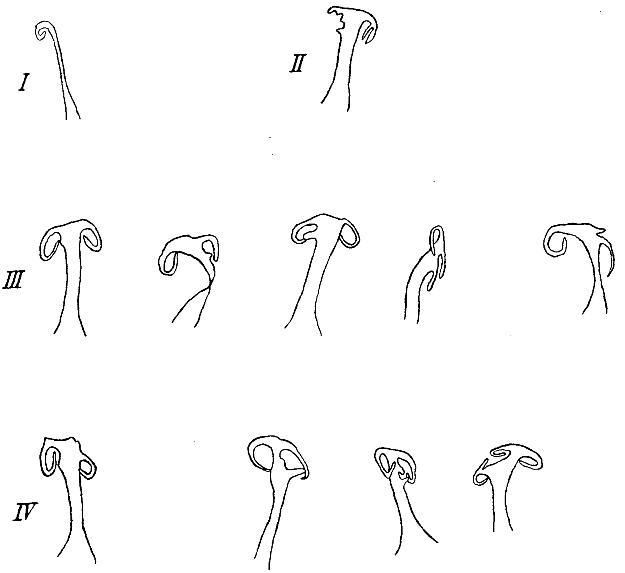

FIG. 9. — Abnormal forms of hooks. *I*, type with only one claw; *II*, type with bifid claw; *III*, type with additional claw on one side, in first four cases below; in last case above, normal; *IV*, type with double outgrowth; in final case a double-headed hook is formed.

Type I, only one claw.

Type II, a bifid claw.

Type III, an additional claw — on one side.

Type IV, a double outgrowth on one side — producing in extreme cases a hook with two complete double claws at its distal end.

In addition, very rudimentary hooks, mere thread-like spines, are frequently found, often lying outside the typical marginal row. In *P. gelatinosa* these abnormal hooks are apparently even more common. Oka ('90, Pl. XIX, Fig. 35) has figured some of them. They can for the most part be referred to the same four types. The abnormal multiplication of claws in Pectinatella is paralleled by the normal condition in Cristatella, where the radial outgrowths of the statoblasts form grapnels with many claws. The condition in Cristatella is in so far different as the claws stand out in all radii in Cristatella, whereas they lie almost or wholly in one plane in the case of Pectinatella. Also "*Pectinatella Carteri*" has "many lateral claws" to each hook.

Both abnormalities and individual deviations from mediocrity in Pectinatella are thus normal or modal in other species of Phylactolæmata.

Summary. — The hooks on 827 statoblasts of a Lake Michigan Pectinatella were counted. The number ranged from 11 to 21; the mode was 13; average, 13.782 ± .031; and index of variability, 1.318 ± .022. The skewness was + 0.077; that is, the variation tends in the direction of the larger numbers, and this is correlated with the fact that species or races of Pectinatella with much larger numbers of hooks occur. There is a slight hereditary tendency in the statoblasts from one colony, about 0.1 when 1 is the maximum inheritance. There is an inverse correlation (of − .092 ± .006) between the number of hooks and the perimeter, and a larger one between number and size of hooks. The number of hooks is thus not determined by room, nor does it seem to be predetermined from an early stage of development of the statoblast. The hooks show abnormalities, some of which resemble the normal condition of hooks in Cristatella.

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